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# MANUAL AND AUTOMATED LINE GENERALIZATION AND FEATURE DISPLACEMENT — APPENDIXES

Steven Zoraster
Dale Davis
Marc Hugus

ZYCOR, Inc.
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Austin, Texas 78741

JUNE 1984

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The primary objective of this effort was to examine map compilation techniques used for manual and automated line generalization and feature displacement. Manual techniques used at several Defense Mapping Agency compilation sites are described in detail. An extensive survey of algorithms suggested in the cartographic, image processing, and computer science literature is provided. Possible criteria for evaluating algorithm performance are discussed and line generalization algorithms are ranked according to certain of these measures.

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APPENDIX A

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## APPENDIX B
## KEYED BIBLIOGRAPHY

This appendix is designed to provide quick reference for the specific line generalization and feature displacement algorithms as outlined in sections 4 and 5. Some articles discuss several algorithms and are therefore listed in different sections. A complete bibliography can be found in Appendix A.

### LINE GENERALIZATION ARTICLES:

#### 4.1 SIMPLE SELECTION:


Rhind, D.W., "Generalization and Realism Within Automated Cartography", The Canadian Cartographer, Vol. 10, Pages 51-62, 1973.

Robinson, A., R. Sale and J. Morrison, Elements of Cartography, Fourth Edition, John Wiley and Sons, New York, 448 Pages, 1978.

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#### 4.2 LOW PASS FILTERING BY MOVING AVERAGES:


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### 4.3 ANGLE SELECTION

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## 4.5 TOLERANCE BAND ALGORITHM

### 4.5.1 Hysteresis Filtering

Duda, R. and P. Hart, Pattern Classification and Scene Analysis, John Wiley and Sons, New York, Chapter 9, 1973.

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APPENDIX C

# COMPILATION GUIDELINES

## C.1 INTRODUCTION

This appendix is included to provide information on the present Defense Mapping Agency guidelines for manual line generalization and feature displacement, however it is not meant to be a thorough discussion of all DMA documents. Several documents were used as a source for this report as shown in Table C.1.

Table C.1

| Title | Source | Date |
|---|---|---|
| TMS-1 Specifications for Military Maps | DMAHTC | November 1977 |
| Contract Quality Control and Inspection, Compilation and Color Separation for Navigation and Planning Charts | DMAAC | March 1975 |
| Contract Technical Procedures, Compilation and Color Separation for Navigation and Planning Charts | DMAAC | May 1977 |
| Map Content Quality Guides | DMAAC | September 1965<br>November 1966 |
| Compilation of Pull-Ups for Medium Scale Maps | DMAHTC | Date unknown |
| Series 200 Technical Specification and Compilation Methods | DMAAC | January 1983 |
| Products Specifications for Joint Operation Grahics, Series 1501 and 1501 Air, Scale 1:250,000 | DMAHTC | November 1976 |
| Product Specifications for Harbor, Approach, and Coastal Charts, Scale 1:6,000,000 and Larger | DMAHTC | September 1966 |
| Products Specifications for 1:50,000 Scale Topographic Maps for Foreign Areas | DMAHTC | July 1980 |

The Contract Quality Control and Inspection document and the Contract Technical Procedures for Compilation and Color Separation document are supplied to external contractors by DMAAC. The remaining documents are used internally at either DMAAC or DMAHTC. In all cases, the documents are provided and the recommendations outlined so as to insure consistency between cartographers and among map products.

Not surprisingly, these documents are incomplete sources of information for line generalization and feature displacement and provide only general guidelines for feature selection. However, the documents supply very detailed information for map accuracy and feature symbolization. The difference in the amount of information supplied to the user for the various compilation tasks is related to task definition; i.e. the easier the task is to define the more detailed will be the information. The line generalization, feature displacement, and feature selection tasks are difficult to define, therefore the guidelines for these tasks are difficult to outline. Conversely, the map accuracy and feature symbolization tasks are relatively easy to define and have been outlined in detail by the DMA. Consequently, the guidelines for line generalization, feature displacement, and feature selection are fairly flexible and depend upon the scale and detail of the map and the ability of the cartographer, while the guidelines for map accuracy and feature symbolization are strictly outlined and cannot be modified except for the most difficult or complex cases.

One purpose of this report is to compare and contrast the various specifications outlined in the documents. Each of the tasks will be discussed in greater detail below in an effort to indicate the differences between the various specifications. Section C.2 will discuss the guidelines for map accuracy, Section

C.3 will discuss the guidelines for feature symbolization including selection, and Section C.4 will discuss the guidelines for line generalization and feature displacement. Included in each section will be examples of the various requirements and other references to the map compilation documents.

## C.2 ACCURACY REQUIREMENTS

All maps must conform to the guidelines set forth by the National Standard Map Accuracy Requirements. These requirements state that 90% of all features, except those unavoidably displaced, must be located within a pre-determined distance of their true geographic position. The requirements may vary for maps of different scales and purposes (i.e. aeronautic and hydrographic charts). In addition to the National Standard Map Accuracy Requirements, DMA has outlined guidelines for internal accuracy requirements. These internal requirements state that contours, spot elevations, and navigational aids (including topographic landmarks) must be plotted in their true positions wherever possible. The significance of these features may change based on the type of map being created, the scale of the map, the overall information content of the map and the importance of the feature.

Both the National Standard Map Accuracy Requirements and the internal DMA accuracy requirements are outlined in specification documents where necessary. Additionally, the specifications indicate at which stages quality control is performed to insure that the products adhere to the accuracy requirements.

## C.3 FEATURE SELECTION AND SYMBOLIZATION REQUIREMENTS

### C.3.1 Feature Selection

Considerations for feature selection are based upon map legibility. As stated above, the selection of map features

is vaguely outlined in all of the compilation guidelines. The requirements provide the user with very general information and several sample cases outlining the selection process. For example, the TMS-1 Guidelines include the following general statements: "The amount of detail to be shown is directly related to the physical and economic importance of the area under consideration, and to the importance of the drainage features as related to other drainage, cultural and hypsographic features shown on the map. Other prime governing factors are, the scale and purpose of the map. The amount of detail should increase in an inverse ratio to the amount of the existing water resources." "The minimum lengths of the streams and the minimum sizes of areal features to be shown must be left to the judgment and cartographic experience of the compiler. Only he can properly evaluate the relative importance of the features by selecting those which for the area and map scale will best satisfy the purpose of the map. Thus the criteria contained in these specifications are intended only as general guidance and not as rigid practice." Therefore, as outlined in the TMS-1 Guidelines, "the selection of map features involves experience and an appreciation of the intent of the map", and therefore leaves many of the decisions for the cartographer.

### C.3.2 Feature Symbolization

The manuals provide very strict guidelines for feature symbolization. These are specific and cover all cases of point, line, and area symbolization, including the type and size of symbols to be used. Each section within the TMS-1 Guidelines contains a reference table with the feature specifications completely outlined. The table lists the information for line weight, line length, and spacing for the various map symbols, as well as providing pictorial examples of how the features should

appear. Also included in the TMS-1 reference table are specifications for lettering. These guidelines are similar to the symbolization guidelines; being highly specific and including information on point size and letter font. Tables C.2 and C.3 are examples of the information portrayed in these tables. Table C.2 is an example of some the information supplied for relief data, i.e. contours and spot elevations, while Table C.3 is an example of some of the data supplied for hydrographic data, i.e. shoreline and special cases of inland hydrography. The tables clearly display the feature and provide all pertinent information, including special information in the form of remarks.

## C.4 LINE GENERALIZATION AND FEATURE DISPLACEMENT REQUIREMENTS

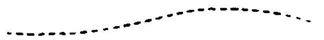
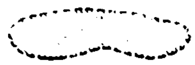
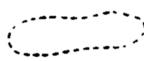
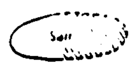
### C.4.1 Feature Displacement

Line generalization and feature displacement techniques are not explicitly outlined in any of these documents. In general these techniques are performed at the discretion of the cartographer. Many of the guidelines for feature displacement requires that linear features be no closer than a given distance or that point features be positionally accurate even after being enlarged for legibility. Therefore, important features which are closer than the given distance are displaced. For example, the TMS-1 Guidelines provide the following example: "If two railroads are in juxtaposition, that is, closely parallel but on separate roadbeds, each line is symbolized individually. If the distance between the roadbeds is too narrow to plot to scale, the space is exaggerated to 0.012 inch (0.30 mm)." However, the TMS-1 Guidelines require that displacement be held "to the absolute minimum consistent with map legibility" and therefore

| RELIEF | | | | |
|---|---|---|---|---|
| | FEATURE | SYMBOL | REMARKS | SYMB NO |
| CONTROL | Spot elevation, normal | •240 •240 | | 509 |
| | Water surface elevation | 75 | | 510 |
| | Glacial or snowfield elevation | •3426 | | 511 |
| | Contour value | 4000 | | 512 |
| CONTOURS AND FORM LINES | Index contour | | | 513 |
| | Intermediate contour | | | 514 |
| | Supplementary contour, one-half interval | | | 515 |
| | Supplementary contour, one-quarter interval | | | 516 |

Table C.2. Example of Reference Table for Feature Relief Symbolizati
from TMS-1 Specification for Military Maps

## DRAINAGE - INLAND HYDROGRAPHY

| | FEATURE | SYMBOL | REMARKS | SYMB NO. |
|---|---|---|---|---|
| SHORELINES | **Definite** |  Lineweight .008" | | 601 |
| SHORELINES | **Indefinite or unsurveyed** |  Lineweight .008" Dash .04" Space .02" | | 602 |
| SHORELINES | **Pinpoint islands** |  | Show to scale<br>Label on compilation<br>Note for retention in reproduction<br>Minimum size .01" | 603 |
| LAKES AND PONDS | **Perennial** |  Lineweight .008"<br>TPC TP 1 | Add tint or label "W" on compilation | 604 |
| LAKES AND PONDS | **Intermittent** |  Lineweight .008" Dash .04" Space .02"<br>TPC Pattern 203 at 45° angle (NW SE) | | 606 |
| LAKES AND PONDS | **Dry or cyclical in arid areas** |  Lineweight .008" Dash .04" Space .02"<br>TPC Pattern 174 | Hand draft dots on compilation<br>Label if appropriate | 605 |
| LAKES AND PONDS | **Salt lakes or ponds (perennial or intermittent)** |  | | 607 |
| LAKES AND PONDS | **Reservoir (natural shoreline)** |  | | 608 |
| LAKES AND PONDS | | | | 609 |

All type 6 pt Spartan Medium Italic C/L

Table C.3. Example of Reference Table. Drainage Symbolization from TMS-1 Specifications for Military Maps

leaves this decision up to the cartographer. The remaining features are compiled and plotted in their true positions, insofar as the National Standard Map Accuracy Requirements are maintained.

### C.4.2 Line Generalization

The documents contain few specifications for line generalization. One such specification, found in the Product Specifications for 1:50,000 Scale Topographic Maps for Foreign Areas, the Product Specifications for Joint Operation Graphics, Series 1501 and 1501 Air, Scale 1:250,000, and the Product Specifications for Harbor, Approach, and Coastal Charts, Scale 1:6,000,000 and Larger, provides the following general statement for contour lines: "It is required that the user be presented with the maximum graphic information that is consistent with the scale and operational use of the map. If there is an extreme scale difference necessitating reduction between the source material and the compilation, the contours should be generalized by smoothing the fine detail but retaining the basic shape." In addition to the above statement, the Product Specifications for Joint Operation Graphics, Series 1501 and 1501 Air states that "he (the user) be fully aware of its (the map) accuracy". Therefore, in these three specification documents, the cartographer is provided with valuable guidelines for both the technique and the requirements for generalized contours. However, the cartographer is not provided with such extensive guidelines for other features in these or other documents. For example the Contract Technical Procedures for Compilation and Color Separation provide the following guidelines: "Some generalization of contours is automatically achieved during the compilation process. Contour pull-ups from large scale source materials are normally generalized at the pull-up (selection overlay) scale.

Further generalization is then accomplished when preparing the contour overlay from the reduced pull-ups. The amount of generalization varies with the scale of the chart being produced. The JOG, 1:250,000 scale, retains greater character and very little contour generalization, whereas the ONC, 1:1,000,000 scale, has increased generalization resulting in smoother flowing lines with fewer kinks and wiggles." "Contours must be aligned to conform to spot elevations, cuts, hills, lakes and linear features. Where contours cross valleys, the inverted 'V' or 'U' must always point uphill." "The area on the high side of a generalized contour should include all ridges higher than the contour, while the valleys between these ridges may be eliminated through contour generalization."

Consequently, this task depends primarily on the ability of the cartographer to interpret and resolve conflicts while satisfying the National Standard Map Accuracy Requirements. Therefore, it is important for the cartographer to be provided with and have knowledge about the area being mapped. This allows him to select those features which are most significant and provide the greatest information content.

## C.5 CONCLUSIONS

While the guidelines for feature selection, feature symbolization, and map accuracy are fairly well defined, the specifications do not discuss line generalization or feature displacement in detail. This is a result of the difficulty in defining these tasks and the lack of guidelines, in any form, which sufficiently outline the manual techniques for either line generalization and feature displacement. Therefore, line generalization and feature displacement are left largely to the discretion of the cartographer.

Given the limited consideration of line generalization and feature displacement and the overall flexibility of the specifications, it is possible that maps of the same area generated by different cartographers may be different, yet these maps will all be within the accuracy requirements. Finally, consistent products are less likely if many of the decisions are left to the discretion of the cartographer, as is the case with many of the specifications discussed in this appendix.

## APPENDIX D
## DMA COMPILATION PROCEDURES

This appendix contains detailed descriptions of methods used to compile maps at 4 compilation sites at 3 different DMA facilities.

### D.1 DMAAC COMPILATION PROCEDURES

At DMAAC ZYCOR observed manual production techniques being utilized to create Series 200 charts for the Strategic Air Command. These 1:200,000 scale charts are used by SAC for training over the continental U.S. and for mission planning and navigation over foreign territory. The charts ZYCOR saw were for domestic use.

#### D.1.1 Significant Features

These charts support aerial navigation by both visual and instrument techniques. They are intended for use during strategic bombing missions. Thus the significant features on the Series 200 charts include: military installations, industrial sites, all features with significant radar cross sections, features which would provide quick references for visual positioning and ridge lines.

#### D.1.2 Sources

Cartographic sources being utilized are 1:24,000 and 1:62,500 scale USGS maps, maps produced by local government agencies, when available, and photographic sources.

D.1.3 Compilation Process

For these products the customer required that the compilation be a two step procedure. This is represented graphically in Figure D.1. The first step involves pull-up creation to be used in the reduction from source scale to 1:125,000; the second step, compilation from 1:125,000 to the final 1:200,000 scale. Generalization occurs during both pull-up stages. The process is performed in several steps to increase the accuracy and reliability of the maps.

D.1.4 Comments

D.1.4.1 Special Techniques Utilized

At the first stage cartographers were intentionally overcompiling feature data, picking up an estimated 10% more detail than would be required by the final product. This overcompilation was corrected at the second compilation stage when going from the 1:125,000 intermediate product to the 1:200,000 final product.

D.1.4.2 Displacement

The feature displacement is difficult to quantify for the Series 200 Charts since it may be done during any of the two compilation steps, or occasionally by the engraver. This makes exact quality control difficult. New information may be added at any point which may result in added mapping conflicts.

Feature displacement for these maps follows a two level hierarchy. The first hierarchy includes critical features which will, if possible, be shown in their true position and will only be moved for each other in the following order: airfield runways; annotated features, e.g., bridges, dams, and located object symbols; vertical obstructions; drains; and bright and weak

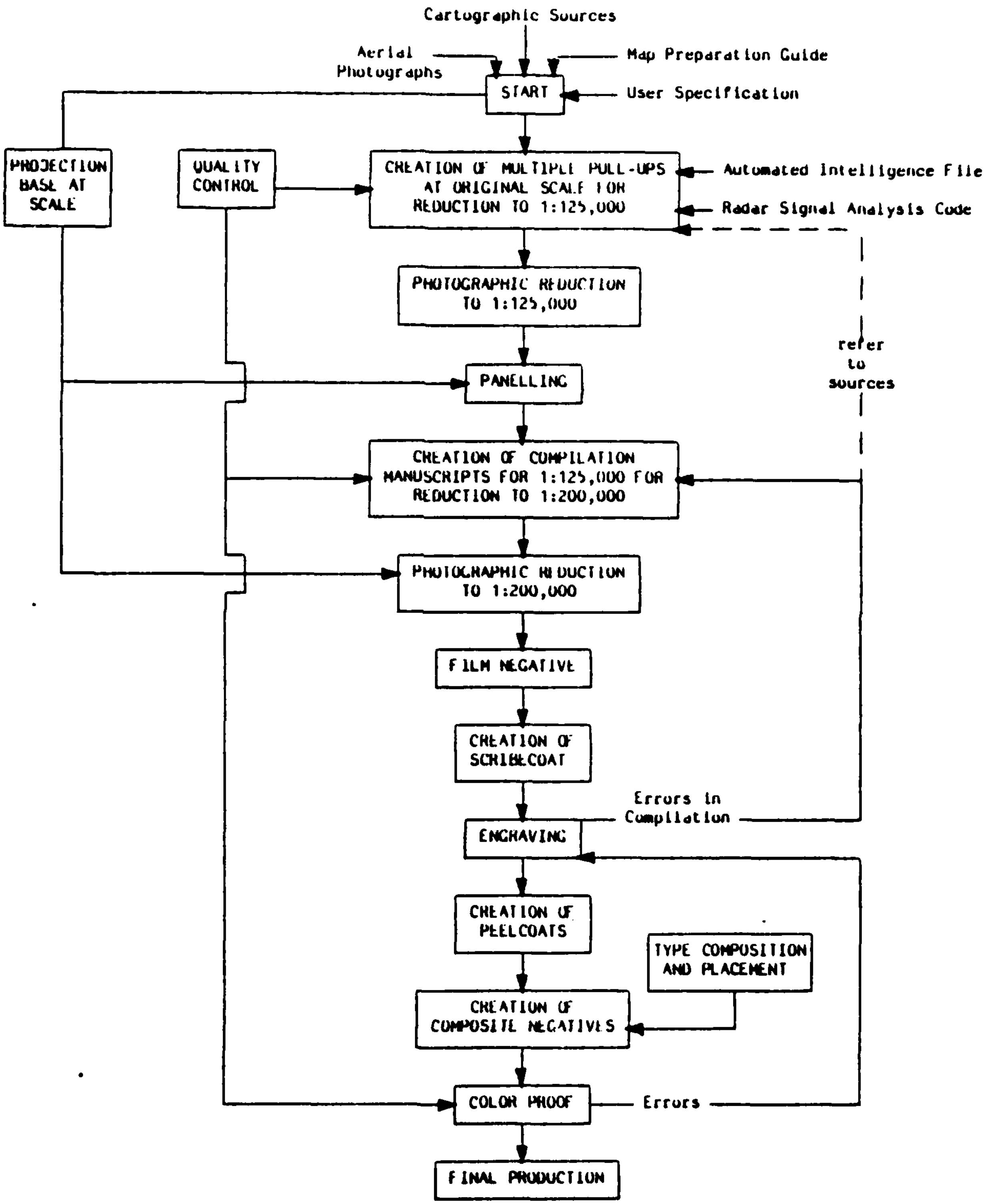



Figure D.1. Procedures for Series 200 Domestic Charts at DMAAC

radar returns. All other features will be adjusted away from these. If none of them is involved, the following order of holding to position should be followed: railroads; roads; circular radar village symbols; power lines; unannotated location objects; spot elevations; and finally contours.

The most difficult decisions to make in feature displacement involve situations where there is no room to move features, such as when a road and a railroad are sandwiched between an airfield runway and a drain. In extremely difficult decisions involving displacement, the cartographer has the freedom to modify symbolization and classification of features if that is the only way to include them on the map without destroying the feature character which must be retained. For example, in a case where a primary road must pass between two features which cannot be moved, but will not fit using the standard line weight, it is permissible to reclassify it as a secondary road in that region if the resulting reduction in line weight will resolve the problem.

### D.1.4.3 Quality Control

These maps are subject to quality control at the compilation steps and after completion of the finished product. Quality control is a time consuming and difficult task because of the size and complexity of the maps produced. Often in checking a final product for errors only the most dense parts of the map are sampled and checked. As a result other portions of the map may contain unchecked errors.

In addition to detection of gross errors, quality control checks line generalization and feature displacement on the map. There are guidelines which are to be followed in both instances, however, feature displacement is viewed as the primary

problem and is therefore scrutinized more closely. Line generalization is not expected to be a problem and cannot be as easily scrutinized.

The cartographers emphasized their difficulties with the existing specifications. If explicit specifications were written and followed by both in-house and outside cartographers many of the problems would be overcome. At present the specifications are not adequate to handle all possible generalization and displacement problems.

#### D.1.4.4 Outside Contractors

Outside contractors have a set of specifications to follow when compiling a map for DMAAC. These specifications outline the requirements for feature displacement and line generalization. Should quality control find an error on the maps produced by outside contractors, there are two options; to send it back to the contractor or to fix it in-house. Quite often the error is fixed in-house to save time and the additional problem of dealing with the contractor.

#### D.1.4.5 Responsibilities of the Compilers and Engravers

For these 1:200,000 products final compilation responsibility always resides with the original compiler. The engraver has limited responsibility to adjust the data he has been provided.

## D.2 DMAHTC TOPOGRAPHIC COMPILATION PROCEDURES

ZYCOR observed the creation of a 1:250,000 Joint Operations Graphic (JOG) map for a foreign location. The JOG is intended for: tactical air operations, including close air support and interdiction; pre-flight planning; short range navigation

using dead reckoning and visual pilotage; and operational planning and intelligence briefing. A common base is used for both air and ground use and is intended to simultaneously satisfy the needs of both Air Force and Army users. The JOG air chart contains information unique to aeronautical navigation including elevation tints, radio, navigation and communication facilities, controlled air space and visual aids. The JOG ground chart contains information pertinent to ground maneuvers including road objectives and kilometric distances. All other information is common to both.

### D.2.1 Significant Features

These are tactical maps for air operations. Therefore, the emphasis is on well-defined visual features which can be used for reference purposes in the planning of joint Army and Air Force missions.

### D.2.2 Sources

Sources for the maps ZYCOR saw produced were limited to existing, non-DMA maps of the region. These maps were supplied by the government of the country being mapped, under a mapping agreement with the United States, and were at a scale of 1:50,000.

### D.2.3 Compilation Process

For this product, the cartographers moved from the 1:50,000 sources to the 1:250,000 final mosaic in one compilation step. This is shown graphically in Figure D.2. Three pull-ups were created for each source: cultural data with drainage, relief data, and vegetation.

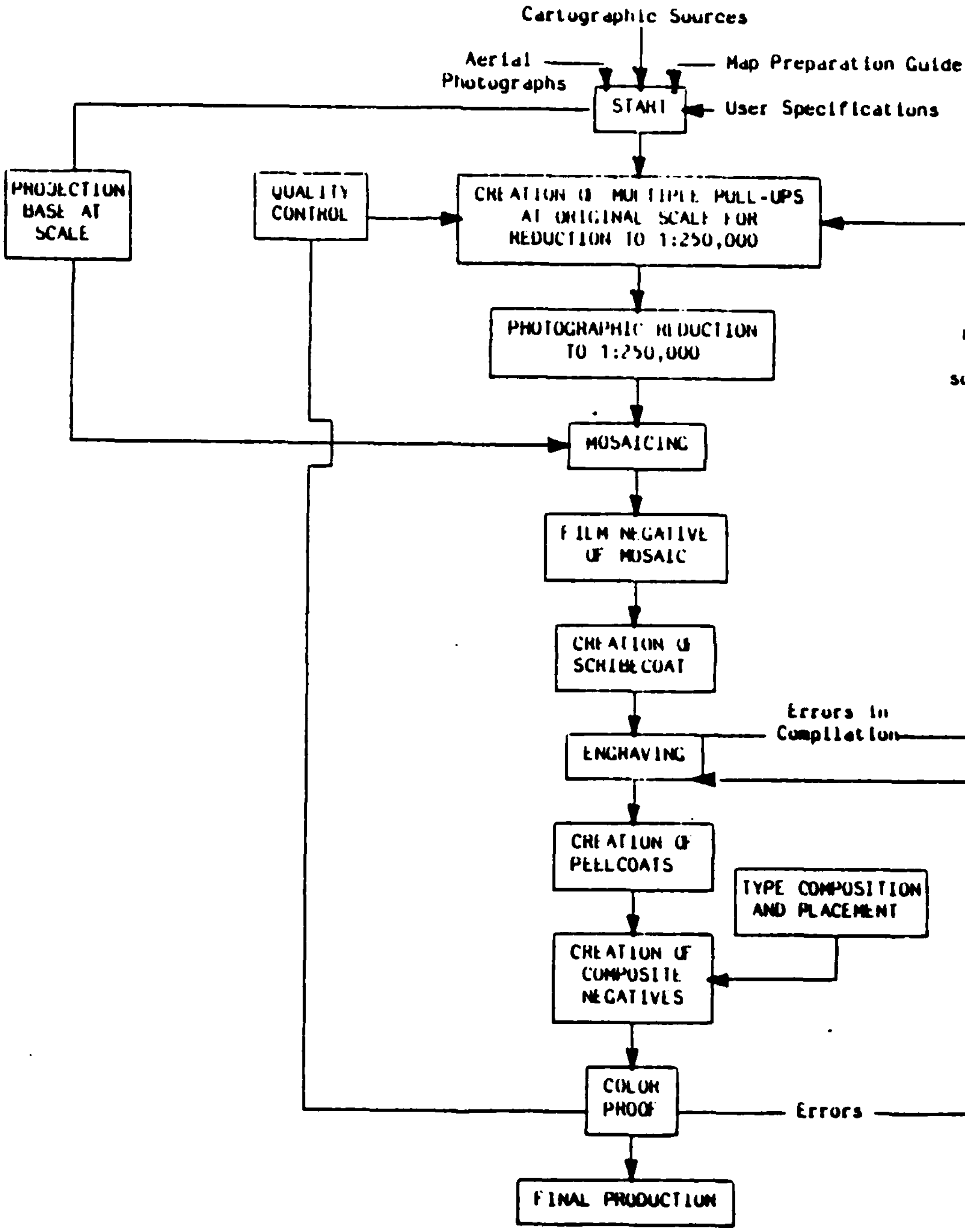



Figure D.2. Compilation Procedures for a 1:250,000 JOG at DMAHTC

D.2.4 Comments

D.2.4.1 Specialized Techniques

For these JOG products, the compilers were giving the highest priority to drainage. Drainage was done first on the pull-ups and other detail tied to the drainage.

The nature of the source dictated that the compilation process involved a great deal of simplification of several features into one symbol, such as several buildings grouped and represented in one symbol. Selection also occurred often at the compilation step, involving the elimination of small islands, lakes, or short line segments, depending on the scale and the importance of the feature.

For this product ZYCOR also saw a certain amount of difficulty in mosaicking the pull-ups together as they involved contours which did not match at edges and symbology which changed from pull-up to pull-up. None of these were particularly serious problems although they were noticeable under close study. The cartographers mentioned that a tendency to over compile was a serious problem for compilers.

D.2.4.2 Line Generalization

Since over-generalization is difficult to detect and positional accuracy is more important, more leeway is given to generalization than is given to displacement on these maps.

Contours are regarded as difficult to generalize and still hold to character. In any case, contours are considered to be only background data and the character or position is sacrificed if necessary.

### D.2.4.3 Displacement

In situations involving extremely difficult displacement problems it is regarded as permissible to simplify things a great deal. For example, given a situation in which a drain crosses a road several times at source, it is permissible to hold it to the predominant side in pull-up.

### D.2.4.4 Responsibilities of Engravers and Compilers

Minor generalization and displacement may be accomplished by experienced engravers. Major problems should be returned to the cartographer.

## D.3 DMAHTC HYDROGRAPHIC COMPILATION PROCEDURES

The Hydrographic Cartography Branch is responsible for producing nautical charts of non-US coastal waters. These are used by general mariners and by the military. They can be broken into three categories: harbor charts (scale greater than 1:50,000) designed to enable the mariner to safely enter, leave, and utilize harbor facilities, approach charts (scale 1:50,000 to 1:300,000) and coastal charts (scale less than 1:300,000) used for coastal navigation.

### D.3.1 Sources

Sources for these charts are usually foreign charts or topographic maps, aerial photographs, hydrographic surveys, and random collection efforts by the Navy or merchant ships.

### D.3.2 Significant Features

Significant features on these charts include shorelines, river mouths, vegetation and landform, radar significant and visible features, spot elevations and contours. Because these

charts are used for navigation, they are required to be highly accurate. This implies a restriction on the amount of generalization and feature displacement unique to these products. Every attempt is made to represent the shoreline as exactly as possible. Soundings are always positionally accurate. More detailed navigational information is carried on harbor charts and either omitted or generalized on the smaller scale charts.

Priorities for feature displacement are also unique. Point features are given priority over lines. For example, soundings are given priority over bathymetric lines and lighthouse symbols are given priority over the shoreline. Manmade features which are straight or angular retain their character on smaller scale maps.

### D.3.3 Compilation Processes

At this site, compilation could involve one or more reduction steps depending on the scale changes involved and the amount of detail on the sources. For example, in a case for which 1:15,000 sources were being used to create 1:300,000 outputs, a first step went from 1:15,000 to 1:75,000 and a second step for 1:75,000 to 1:300,000. Where needed, an inset map at a larger scale is created from a source document before the completion of the primary map. This insures that the smaller scale map does not contain more information than the larger scale inset map.

### D.3.4 Comments

#### D.3.4.1 Accuracy

As mentioned above, accuracy for navigation purposes is very important. Where the mapped data is imprecise or inaccurate it is represented in italicized type or by dashed lines.

There are unique requirements for bathymetric contour placement. When there is uncertainty as to their exact location or they must be displaced around point soundings, they are always moved seaward to reduce the possibility of groundings.

D.3.4.2 Techniques for Supplementary Products

Several special purpose charts are available with modified display; these are produced using a variety of different methods. Navy sounding charts are used to create depth curve charts. The soundings on these charts are positionally accurate; however, the curves are generated by hand and are approximate. Where the depth curves converge, the lines are broken at the overlap to reduce the amount of clutter.

Bottom contour charts differ from depth curve charts in that all bottom contours are shown and are as accurate as possible, similarly the soundings are shown in their true position.

D.3.4.3 Displacement

At present there are no written rules for displacement for these hydrographic products. However new specifications are being written. In general, the amount of generalization or displacement depends on the importance of the area.

D.3.4.4 Responsibilities of Compiler and Engraver

In this section engravers do not edit data. This restriction is due to the extreme importance of accuracy for all features in navigation charts. All errors discovered must go back to the compiler.

D.4 <u>DMA SAN ANTONIO TOPOGRAPHIC COMPILATION PROCEDURES</u>

The Defense Mapping Agency's field office in San Antonio, Texas does many of the same cartographic tasks performed

at the main DMA offices. It also performs data collection from photographic sources. The data which is collected from the photographic sources is used in the generation of topographic, hydrographic, and aeronautical maps and charts at the San Antonio field office, as well as at other Defense Mapping Agency facilities.

### D.4.1 Products

The compilation site visited at this office produces 1:50,000 tactical maps. Currently these are the largest scale tactical planning maps utilized by the Army.

Much of the input data for these 1:50,000 maps is at the same scale. Since ZYCOR is studying the generalization process for construction of small scale maps, the San Antonio office went through an exercise of creating the pull-ups required for creation of 1:250,000 maps from the same sources.

San Antonio is involved in original data collection of cartographic information from stereo photographic sources. For this purpose it operates a state-of-the-art stereo compilation system.

### D.4.2 Sources

Sources for map compilation observed at this office were unique in that relief data was being created on site at a scale of 1:50,000 from stereo sources using a stereo compilation system operated only by the San Antonio office. This system, the Digital Stereo Compilation System (DSC) which is produced by Bendix is discussed below and in greater detail in the Appendix E. Unrectified, non stereo photographs and various non-standard cartographic sources were relied on for feature data.

D.4.3 Significant Features

The 1:50,000 products which San Antonio produces are used for tactical purposes by the United Stated and allied armies. Thus these products demanded the highest level of concentration on detail in local relief.

D.4.4 Process

D.4.4.1 Stereo Compilation

The DSC stereo compilation system utilized at this site provides immediate inputs to the map compilation phase. Although it is not usually thought of as such, a type of generalization inevitably occurs during the stereo compilation. This generalization is produced by a combination of human and system factors. How accurately the operator tracks at the same contour is one factor. Another is the magnification factor at which the photos are displayed, which varies from compiler to compiler according to personal preference. Finally, software in the system controls the frequency at which digitized contour points are recorded thus interacting with the human operator in a manner to create generalization.

Experienced stereo compilers tend to generalize more than less experienced compilers. Quite often the generalization is based on the knowledge of how the data will appear at the target scale. ZYCOR observed a very senior stereo compiler at work. During this demonstration examples of features on the ground which required feature displacement to be performed were parallel features. This compiler was holding one fixed while he moved the other.

D.4.4.2 Manual Compilation

At the time ZYCOR observed manual compilation procedures at the San Antonio office the cartographers were using out-

put from the DSC as a cartographic source for terrain data in compiling 1:50,000 maps. The remaining data (including cultural features, roads, and drainage) was collected onto pull-ups from unrectified aerial photographs and certain commercial map sources. Feature data such as roads and drains which had been captured on the DSC were utilized only for registration purposes. Since the final product and the sources were at the same scale, there was no generalization performed in this compilation. The aerial photographs were not reduced to a smaller scale to simplify the creation of the photographs because there might be discrepancies in registration between the two data sets.

To facilitate ZYCOR's research, the compilation section went through the exercise of creating pull-ups from the 1:50,000 DSC data as a source for a 1:250,000 map. The entire process involved a one step compilation from source scale to output scale.

### D.4.5 Comments

#### D.4.5.1 Special Techniques Utilized

The line generalization and feature displacement are controlled through the use of different line weights. The different lineweights are achieved by using felt-tip markers of varying thicknesses.

Line generalization is inherently accomplished by using the felt-tip markers. Where a very sinuous line is being traced with a wide marker, the line is "automatically" generalized because the entire character of the line cannot be captured with a wide line.

The drainage is used as the skeleton away from which all other data is displaced.

D.4.5.2 Feature Displacement

Satisfactory guidelines do not exist for map generalization or feature displacement. However, the recognized displacement priority is drainage, cultural data, and finally roads

D.4.5.3 Responsibilities of Engravers and Compilers

The engraver may add additional generalization or displacement to the product. The engraver is particulary responsible for smoothing differences between compilers.

D.4.5.4 Quality Control

There are several stages of intermediate quality control at the San Antonio field office. During the pull-up stage a very quick and cursory review of the pull-ups is done. At the final stage, prior to release of the map or chart, the product is thoroughly reviewed.

## APPENDIX E
## DMA AUTOMATED TECHNOLOGY

### E.1 INTRODUCTION

Several of the automated cartographic systems currently utilized by DMA are discussed in this section. The first two, the Automated Graphic Digitizing System (AGDS) and the SCI-TEX cartographic system, have rudimentary line generalization together with feature displacement capabilities and are included for that reason.

The third system is the Digital Stereo Compilation System which is used only at the DMA San Antonio Office. This system is an example of the process which may be used in capturing a data base for automated cartographic purposes at DMA.

### E.2 AUTOMATED GRAPHIC DIGITIZING SYSTEM

The AGDS is an automated system for the collection, processing, and formatting of digital cartographic products. This system has the potential to perform much of the map compilation process when used in conjunction with a photographic plotter and is currently being used on an experimental basis to supply digital data to DMA VAX based TES/EMPS work stations. Data can be collected for the AGDS either by manual digitization or automated scanning of cartographic sources.

To make use of the automated procedure, a laser scanner must individually process a number of map overlays (one for each type of data). This scanner operates under control of a PDP 11/34 computer. The scanner collects the data in raster format at a resolution of down to two thousandths of an inch at both centers.

After the overlay has been scanned, the data is moved to a PDP 11/60 where a transformation from raster to vector format is accomplished. Finally, the data is transferred to work stations at which various editing and tagging operations are performed. Work stations are supported by PDP 11/70's at the rate of 5 stations to one computer. Each work station has a digitizing table and 2 Tektronix display terminals.

While certain editing tasks such as contour tagging are still manual processes, others have been fully automated in a software package known as the Automated Edit Program (AEP). The AEP has three subprograms, each of which deals with different problems. The subprogram INODES is a nodalization program which combines line segments that share common nodes. The AGCP subprogram bridges gaps in digital line segments and performs closure on area features.

Of more interest for this report is the subprogram NFTP. It is designed to reduce line noise created during the scanning and vectorization process. Based on filtering tolerances it contains algorithms to remove high power noise and low power noise and to eliminate coincident points and stick features. The filter tolerances used depend on line weights of input manuscripts, collection method (scanned or digitized), project type and source material (compilataion or photographic).

Part of the code developed used in the NFTP is based on an algorithm developed by the German firm, A.E.G. All source code for this subprogram was written in-house by DMAAC/CDCT. This algorithm produces line smoothing and could be used for map generalization. However, noise reduction remains its primary use. Data compaction has been a useful side effect with reduction of data running between 40% and 80%.

## E.3 THE SCI-TEX CARTOGRAPHIC SYSTEM AT DMAHTC

### E.3.1 Overview

The Automated Raster Cartographic System (ARCS) is an experimental automated data collection, editing, and production system to be used in the generation DMA format maps from foreign series maps. The Sci-Tex Response 250 Mapping System (R250/MS) is a subsystem of ARCS, and, as delivered to the DMAHTC, consists of a high speed raster scanner, four edit stations, and a laser plotter. The system is being evaluated on two points: 1) the system must be able to produce color separation film positives or negatives from paper copy, and 2) the system must have the capability to modify the data prior to the actual production of the separations. A general overview of the Sci-Tex Response 250 Mapping System follows.

### E.3.2 Chart Analysis and Scanning

The R250/MS raster scanner is a high speed drum scanner (130 revolutions per minute) with variable scanning resolutions. The scanner is capable of scanning either transparent or opaque, single or multiple color source documents. Each multiple color source document can be scanned with a maximum of 12 colors. Source documents up to 36 x 36 inches can be scanned. Data is captured and stored using run length encoding.

Prior to scanning the source document, the operator examines the map and creates a color table of all colors present on the map. The color table may contain up to 12 individual colors for comparison and contains both discrete colors and shades of colors since each unique color or shade is treated as an individual color by the scanner. During the scanning stage the color at each scan cell is sensed and compared to the color table to determine which it most closely resembles. Once the

color has been determined it is stored along with the x and y coordinates of the cell. If the scan cell is located on the interface between two colors, if the color is not clearly defined, or if the scanning resolution is too coarse, erroneous colors may be stored and this data will require editing.

### E.3.3 Data Editing and Modification

Each R250/MS edit station consists of a 19 inch color display console with a special function keyboard and an alpha-numeric terminal, a tablet digitizer and cursor, and a teletype. Editing is an interactive and automatic task which involves displaying the data on the color display console and determining where editing is necessary. A 12 color raster file can be displayed in whole or part on the color display console. Areas of color that interface on the source document will appear as lines of bad data between areas of homogeneous color and bad data points will appear as incorrect color in a homogeneous area. These areas can be edited in one of two ways; 1) the operator can run a program which will change the color in an area (providing it with the correct color and the limits of the area), or 2) the operator can run a program which will allow him to trace an area of bad data with the cursor and change the color. In either case the operator must be careful not to input the wrong area since it could change good data to bad. Once the data has been edited, the data is modified to form a separate file for each color; these files are used to make the separated film positives or negatives. Additionally, the modifications involve changing the foreign text to English and changing certain symbols to DMA format.

### E.3.4 Color Separation

From the editing stage, the data is transferred to the laser plotter upon which separated film positives or negatives are made. The plotter is a variable resolution film exposure unit which can handle output up to 42 by 75 inches. Film is mounted on the drum of a laser plotter and as the plotter head passes over the film the laser exposes the film to light in the pattern determined by the separation file it is plotting.

### E.3.5 SCI-TEX Generalization Operations

The SCI-TEX has the capability to be used in displacement and generalization operations. Feature displacement is an interactive process. For example, to displace a linear feature each node must be "visited" and moved under operator control. Generalization is an automated procedure which can take place at two stages. By choice of parameters, it can be done as part of a raster to vector conversion. It also can be done on the vectorized lines. In the latter case, a proprietary SCI-TEX algorithm is used.

## E.4 DIGITAL STEREO COMPILATION SYSTEM

The Digital Stereo Compilation System (DSC), developed by the Bendix Corporation, is a PDP based system used for digital data capture from aerial stereo-photographs. At present the DSCS is used in the compilation of relief data at a scale of 1:50,000 from stereo photographs. This data is then utilized in the compilation of 1:50,000 and 1:250,000 scale maps.

As implemented at the San Antonio office the DSCS operates on six PDP minicomputers. The six PDP minicomputers are configured so that two of the computers function as the host system and the remaining four computers are used for data

collection. Each PDP minicomputer includes an alphanumeric display terminal, a graphic display terminal, and a teletype terminal.

Aerial stereo-photographs are placed on the plotter unit and registered by means of the fiducial points in the corners of each photograph. Once the two aerial photographs are registered, the contour data can be collected. Starting at a point of known elevation, the operator traces the contour by manipulating a spot of light along the photographs at the same elevation. This process is done for all the desired contours.

Data collection is influenced by a number of factors. First, the operator must follow the contour. The more effort he puts into this task the more detail will be obtained. Second, the operator has the freedom to choose whatever magnification factor he is most comfortable with. Greater magnification implies greater detail. Finally, software in the DSCS controls the rate at which data points are collected.

# APPENDIX F
# MAP GENERALIZATION SURVEY

The difficulty associated with the automation of generalization and feature displacement is in part due to a lack of quantitative information about a highly artistic process. Defining a knowledge base to support the automation of such a complex procedure is a project beyond the resources of this contract. However, it was possible to make a start by interviewing DMA cartographers and by developing a survey questionnaire to further investigate certain facets of the problem.

## F.1 SURVEY GOALS

The survey was prepared by ZYCOR in consultation with ETL and DMA for completion by cartographers at DMAAC and DMAHTC. Three major goals were:

- to identify limits to the automation of map generalization by learning how often "difficult" problems are encountered,
- to identify line generalization and feature displacement processes which must be included in any automated system intended to approach the performance of manual compilers and conversely, to identify processes which may be left out of an automated system because they are of relatively low importance to DMA, and
- to identify areas in which there are significant variations in compilation practices for which multiple algorithm options would be required in an automated system.

Also, certain questions were designed to obtain information about limitations in manual methods and to identify technical approaches used in solving particular generalization prob-

lems. The survey itself is shown in Figure F.1. The responses from all valid surveys are shown in Table F.1.

## F.2 SURVEY ANALYSIS

The survey was presented to DMA cartographers by DMA personnel familiar with this contract but not involved in the development of the survey. Unfortunately there were difficulties associated with the interpretation of certain questions which could not be resolved at the time the survey was performed. Also some questions required single answers to problems which varied with the scale of the product being produced or the source of input data.

A major error in the survey development was the limited attention paid to the special requirements of nautical charts. Many questions in the survey were of only marginal importance to the cartographer working on those products. A number of the respondents from the Hydrography Department at DMAHTC left all questions unanswered. While most provided answers to many of the questions it was decided to leave responses by the Hydrography Department out of the analysis of the survey.

No attempt has been made to perform sophisticated statistical analysis of the survey data. The relatively small size of the sample, problems associated with missing or multiple answers to individual questions, and the relatively unstructured way in which the survey was performed would make the validity of such an analysis questionable.

When studying the survey results the potential gap between perception and fact should be noted. Respondents may be providing answers which correspond to the way they believe the work should be done rather with the way it is actually performed. In certain cases the responses to the survey

Figure F.1

QUESTIONAIRE FOR LINE GENERALIZATION
AND FEATURE DISPLACEMENT STUDY

OVERVIEW

ZYCOR, Inc. has been contracted by the Defense Mapping Agency to study automated map generalization and feature displacement. Three trips to Defense Mapping Agency facilities were made by ZYCOR personnel in an effort to become acquainted with the mapping process. A great deal of information was gained from these visits, however many questions still remain. We are submitting this questionaire in order to better understand how these processes are performed. Please answer the questions carefully. Should you feel that further clarification of your answer is needed feel free to write in the margins or on the back of the page (if you do this please number the response).

In questions asking for a choice among many answers please provide only one answer. If there is a conflict pick the answer which is the most appropriate.

Please return this questionaire by July 1, 1983.

PRELIMINARY QUESTIONS:

1. How many years experience do you have as a cartographer? (include both DMA and non-DMA experience)

   A. less than 2 years
   B. 2-3 years
   C. 4-5 years
   D. 6-7 years
   E. 8-9 years
   F. More than 10 years

2. How many years have you been working at DMA as a cartographer?

   A. less than 2 years
   B. 2-3 years
   C. 4-5 years
   D. 6-7 years
   E. 8-9 years
   F. More than 10 years

3. Other than the training you have received at DMA how many years of formal education in cartography do you have?

   A. less than 2 years
   B. 2-4 years
   C. more than 4 years.

4. In what section of DMA are you currently working?

   ______________________.

5. On what DMA products do you typically work?

   ______________________.

6. What function do you perform most?

   A. Pull-up creation (compilation)
   B. Engraving
   C. Collection of source material
   D. Quality Control
   E. Other ________ ________.

7. Do you work with any automated equipment?

   A. Yes
   B. No (If No then skip to question 9).

8. If your answer to 7 is "yes", please specify equipment and function

| system | function |
|---|---|
| ______________ | ______________ |
| ______________ | ______________ |
| ______________ | ______________ |

GENERALIZATION QUESTIONS:

9. Do you feel it is acceptable to over generalize contours in extremely congested areas of a map?

   A. Yes
   B. No

10. When generalizing contours and drains do you delineate the same amount of detail for the line characteristics from both?

   A. Yes
   B. No

11. When generalizing contours how important is it that they cross roads at right angles?

   1 2 3 4 5
   Unimportant — Very important

12. When generalizing contours how important is it that they show sharp turnbacks when crossing drains?

1 2 3 4 5
Unimportant Very Important

13. If you delete a segment of drainage during generalization how important is it that the generalized contours represent the deleted drainage?

1 2 3 4 5
Unimportant Very Important

14. How important is it to generalize uniformly over the entire final product?

1 2 3 4 5
Unimportant Very Important

15. When generalizing a relief which is more important to represent correctly: contour character or natural feature character?

A. Contour character (line roughness)
B. Feature character (topographic detail)
C. They are of equal importance
D. Neither is important

16. When generalizing a contour what should be emphasized and retained?

A. Ridges on high sides of contour
B. Valleys between the ridges
C. They are of equal importance
D. Neither is important

17. When generalizing contours, how often, do you deviate from the input data to emphasize important features which would not otherwise be visable at the reduced scale?

A. 2 or less times per pull-up
B. 3-6 times per pull-up
C. 7-10 times per pull-up
D. more than 10 times per pull-up

18. How can you tell that you are doing the correct amount of line generalization?

A. By looking at the whole pull-up
B. Comparison with previous work
C. Study of specifications
D. Reference to line weights on the pull-up
F. Other

19. What is the maximum ratio between source map scale and output map scale for one step generalization?

A. Less than 4
B. 4-5
C. 6-7
D. 8-9
E. 10 or larger

20. What is your reason for this answer to question 19?

A. It is a function of the source data?
B. Too many features on the source document may be retained when the scale is reduced more in one step
C. When collecting data onto pull-ups there is a limit to the width of the line which can be used to represent the feature at the reduced scale
D. One sheet at the source scale contains too little information at the target scale to comprehend how it fits in the total product.
E. Other

DISPLACEMENT QUESTIONS

21. Is it permissible to ignore symbolization specification to resolve a difficult feature displacement problem?

A. Yes
B. No

22. Is it permissable to change the classification of a feature to resolve a difficult feature displacement problem?

A. Yes
B. No

23. Are there specific limitations on how much a feature may be displaced on the final product?

A. Yes
B. No (If "No" then skip to question 25)

24. If answer to 23 is "Yes", please describe limitations?

25. Does name placement ever lead to displacement problems?

A. Yes
B. No

Figure F.1 (Continued)

26. How important is it to annotate a feature which has been significantly displaced to reflect its reduced positional accuracy?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Unimportant | | | | Very important |

27. How important is it to have consistent rules for selection for the entire map?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Unimportant | | | | Very important |

28. What percentage of feature displacement decisions involve moving only point data?

A. 81 - 100%
B. 61 - 80%
C. 41 - 60%
D. 21 - 40%
E. 0 - 20%

29. What percentage of feature displacement decisions involve moving line data?

A. 81 - 100%
B. 61 - 80%
C. 41 - 60%
D. 21 - 40%
E. 0 - 20%

30. What percentage of feature displacement decisions involve 3 or more features?

A. more than 50%
B. 26 - 50%
C. 11 - 25%
D. 6 - 10%
E. 0 - 5%

31. What percentage of feature displacement decisions require the amalgamation of features?

A. more than 50%
B. 26 - 50%
C. 11 - 25%
D. 6 - 10%
E. 0 - 5%

32. For what percentage of feature displacement decisions do the available guidelines fail to provide the necessary relative hierarchies?

A. more than 50%
B. 26 - 50%
C. 11 - 25%
D. 6 - 10%
E. 0 - 5%

33. Given a drain and a road following a generally parallel path what should be done if the road crosses the drain several times and the crossings cannot be easily shown at the reduced scale?

A. Straighten out drain to one side of the road
B. Straighten out road to one side of the drain
C. Maintain character of both
D. Delete the overlapping portions of the drain

34. If there is a conflict between a building and a feature defined by a contour, which one has priority?

A. The building
B. The feature defined by a contour

35. How do you handle a political border if it conflicts with a more important linear feature?

A. Move the political border by maintain its character?
B. Move the political border but disregard its character?
C. Delete that portion of the political border.
D. Other

| Question | DMAHTC1 | DMAHTC2 | DMAHTC3 | DMAHTC4 | DMAHTC5 | DMAHTC6 |
|---|---|---|---|---|---|---|
| 1 | 10+ | 10+ | 10+ | 10+ | 10+ | 10+ |
| 2 | 10+ | 10+ | 10+ | 10+ | 10+ | 10+ |
| 3 | 4+ | 2- | 2- | 2- | 2- | 2- |
| 4 | cartog | toac | cartog.anal | cartog.anal | topog.anal | topography |
| 5 | line/photo/picto | color sep | comp and reduc | comp and eng mss | topo mapping | comp.color sep |
| 6 | QC | engraving | engraving | engraving | engraving/sup | QC |
| 7 | yes | no | no | no | no | no |
| 8 | digitization | | | | | |
| 9 | yes | no | yes | no | no | no |
| 10 | no | yes | no | yes | yes | yes |
| 11 | 5 | 3 | 3 | 3 | 4 | 5 |
| 12 | 5 | 3 | 5 | 4 | 4 | 5 |
| 13 | 5 | 3 | 5 | 4 | 4 | 4 |
| 14 | 5 | 3 | 4 | 5 | 5 | 5 |
| 15 | C | A | C | B | C | C |
| 16 | C | C | C | C | C | C |
| 17 | 3-6 | 3-6 | 3-6 | | 3-6 | 10+ |
| 18 | A | A | A | A | E | ABCDE |
| 19 | 4-5 | 4-5 | 6-7 | 6-7 | 4- | 4-5 |
| 20 | B | C | B | C | C | C |
| 21 | no | no | yes | yes | yes | no |
| 22 | no | no | no | no | no | no |
| 23 | yes | yes | yes | no | yes | yes |
| 24 | line wt | line wt | | | .01" | specs |
| 25 | yes | no | yes | yes | no | no |
| 26 | 5 | 3 | 4 | 4 | 4 | 4 |
| 27 | 5 | 3 | 4 | 5 | 3 | 5 |
| 28 | 0-20% | 0-20% | 0-20% | 0-20% | 0-20% | 0-20% |
| 29 | 21-40% | 21-40% | 0-20% | 0-20% | 21-40% | 61-80% |
| 30 | 11-25% | 6-10% | 6-10% | 6-10% | 6-10% | 26-50% |
| 31 | 25-50% | 6-10% | 0-5% | 6-10% | 0-5% | 50%+ |
| 32 | 25-50% | 6-10% | 0-5% | 0-5% | 0-5% | 6-10% |
| 33 | C | C | C | C | C | C |
| 34 | B | A | B | B | B | |
| 35 | C | A | D | D | C | D |

Table F.1 - Survey Responses

| Question | DMAHTC7 | DMAHTC8 | DMAHTC9 | DMAHTC10 | DMAHTC11 | DMAHTC12 |
|---|---|---|---|---|---|---|
| 1 | 10+ | 8-9 | 4-5 | 4-5 | 2-3 | 2- |
| 2 | 10+ | 2- | 4-5 | 4-5 | 2-3 | 2- |
| 3 | 2- | 2- | 2-4 | 2- | 4+ | 2- |
| 4 | carto.anal (toac) | toac | toacl | topog.anal | toac | toac |
| 5 | line maps | line maps | 1/50K, 1/250K | 1/50K, 1/250K | comp/eng | negs |
| 6 | QC | engraving | engraving | engraving/QC | comp/eng | engraving |
| 7 | no | no | no | no | yes | no |
| 8 | | | | | tracing relief/DCR | |
| 9 | yes | yes | no | no | no | no |
| 10 | yes | no | yes | no | no | yes |
| 11 | 4 | 2 | 5 | | 4 | 4 |
| 12 | 5 | 5 | 4 | 4 | 1 | 4 |
| 13 | 5 | | 5 | 5 | 2 | 4 |
| 14 | 5 | 3 | 5 | 5 | 4 | 4 |
| 15 | A | B | C | B | B | C |
| 16 | C | C | C | C | C | C |
| 17 | 10+ | | 3-6 | 2- | 3-6 | 3-6 |
| 18 | B,C | | B,C | E | A | E |
| 19 | 4-5 | | 4-5 | 4-5 | 4-5 | 4-5 |
| 20 | | | C | C | C | C |
| 21 | no | yes | no | no | yes | yes |
| 22 | no | no | no | no | no | yes |
| 23 | no | no | yes | yes | no | no |
| 24 | | | specs | 1 symbol width | | |
| 25 | no | yes | no | no | yes | yes |
| 26 | 2 | 3 | 3 | 5 | 3 | 5 |
| 27 | 5 | 5 | 4 | 5 | 4 | 5 |
| 28 | 0-20% | | 0-20% | 61-80% | 41-60% | 21-40% |
| 29 | 81-100% | | 0-20% | 0-20% | 41-60% | 41-60% |
| 30 | | | 0-5% | 6-10% | 0-5% | 26-50% |
| 31 | 25-50% | | 6-10% | 50%+ | 25-50% | 11-25% |
| 32 | | | 0-5% | 25-50% | 11-25% | 6-10% |
| 33 | C | C | B | B | C | D |
| 34 | B | B | B | A | B | B |
| 35 | D | A | A | D | D | C |

Table F.1 (Continued)

| Question | DMAAC1 | DMAAC2 | DMAAC3 | DMAAC4 | DMAAC5 | DMAAC6 |
|---|---|---|---|---|---|---|
| 1 | 10+ | 2-3 | 10+ | 10+ | 4-5 | 4-5 |
| 2 | 10+ | 2-3 | 10+ | 10+ | 4-5 | 4-5 |
| 3 | 2- | 2- | 2-4 | 2- | 2- | 2- |
| 4 | CDA | CDABC | Cartography | cda | cda | aero cart dpt |
| 5 | nav plan | atm-200 | paper charts | atm/nav/plan | atm/nav plan | nav plan/ATM 200 |
| 6 | pull up/coll/qc | pull up | pull up | review/edit | pull up | pull up |
| 7 | no | no | no | no | no | no |
| 8 | | | | | | |
| 9 | yes | yes | no | yes | yes | no |
| 10 | no | yes | no | yes | no | no |
| 11 | 1 | 2 | 1 | 3 | 1 | 3 |
| 12 | 5 | 2 | 3 | 5 | 5 | 5 |
| 13 | 4 | 4 | 1 | 3 | 3 | 5 |
| 14 | 4 | 5 | 5 | 5 | 3 | 4 |
| 15 | C | B | B | B | B | C |
| 16 | C | C | C | C | A | C |
| 17 | 2- | 3-6 | 2- | 3-6 | 2- | 7-10 |
| 18 | A | A | A,B,C | A | B | A,B |
| 19 | 6-7 | 8-9 | 6-7 | 4- | 6-7 | 4- |
| 20 | A,B,C,D | A | A,B,C,D | A | D | |
| 21 | no | no | no | no | yes | yes |
| 22 | no | no | no | no | yes | no |
| 23 | yes | yes | yes | no | no | yes |
| 24 | tols/specs | common sense | scale, qc manual | | | common sense |
| 25 | yes | no | yes | yes | yes | no |
| 26 | 5 | 3 | 5 | 5 | 5 | 5 |
| 27 | 5 | 5 | 5 | 5 | 4 | 5 |
| 28 | 21-40% | 41-60% | 41-60% | 0-20% | 0-20% | 0-20% |
| 29 | 21-40% | 41-60% | 41-60% | 0-20% | 21-40% | 41-60% |
| 30 | 6-10% | 26-50% | 11-25% | 0-5% | 6-10% | 0-5% |
| 31 | 0-5 | 50+ | 6-10 | 6-10% | 0-5% | 11-25% |
| 32 | 0-5 | 0-5 | 0-5 | 6-10% | 0-5% | 25-50% |
| 33 | C | C | C | C | C | B |
| 34 | B | B | B | B | B | |
| 35 | C | C | C | C | C | C |

Table F.1 (Continued)

| Question | DMAAC7 | DMAAC8 | DMAAC9 | DMAAC10 | DMAAC11 | DMAAC12 |
|---|---|---|---|---|---|---|
| 1 | 10+ | 10+ | 10+ | 2-3 | 10+ | 10+ |
| 2 | 10+ | 10+ | 10+ | 2-3 | 10+ | 10+ |
| 3 | 2- | 2- | 2- | 2- | 2-4 | 2- |
| 4 | CDAA-B | CDA | CDAA-C | CDAAC | CDA | CD |
| 5 | nav plan/ATM/pubs | ser.200/atc | tpc/onc/jnc/gnc | nav plan/ATM | nav plan | ATM |
| 6 | compilation | pull up | pull up | pull up/edit | qc | collection |
| 7 | yes | no | no | no | no | no |
| 8 | computers | | | | | |
| 9 | yes | no | yes | yes | yes | yes |
| 10 | yes | no | no | no | yes | yes |
| 11 | 3 | 1 | 2 | 2 | 3 | 3 |
| 12 | 5 | 4 | 5 | 5 | 4 | 4 |
| 13 | 5 | 3 | 5 | 4 | 4 | 3 |
| 14 | 5 | 4 | 4 | 3 | 5 | 3 |
| 15 | B | B | B | B | C | B |
| 16 | A | C | A | A | C | C |
| 17 | 3-6 | 7-10 | 2- | 2- | 7-10 | 2- |
| 18 | B | E | A | F | B | A |
| 19 | 4- | 10+ | 4- | 4-5 | 4- | |
| 20 | E | C | C | A | B | |
| 21 | no | no | no | no | yes | no |
| 22 | no | no | no | no | no | no |
| 23 | yes | yes | yes | yes | yes | yes |
| 24 | common sense | specs | notation | notation | priorities | |
| 25 | yes | yes | yes | yes | yes | yes |
| 26 | 1 | 3 | 5 | 5 | 5 | 4 |
| 27 | 5 | 3 | 5 | 5 | 5 | 4 |
| 28 | 0-20% | 41-60% | 41-60% | 61-80% | 0-20% | 0-20% |
| 29 | 0-20% | 21-40% | 41-60% | 21-40% | 81-100% | 0-20% |
| 30 | 0-5% | 11-25% | 0-5% | 0-5% | 50%+ | 0-5% |
| 31 | 0-5% | 11-25% | 0-5% | 0-5% | 11-25% | 6-10% |
| 32 | 0-5% | 6-10% | 0-5% | 0-5% | 0-5% | 11-25% |
| 33 | | C | B | B | C | C |
| 34 | B | B | B | B | A | B |
| 35 | C | C | C | C | D | C |

Table F.1 (Continued)

| Question | DMAAC13 | DMAAC14 | DMAAC15 | DMAAC16 | DMAAC17 |
|---|---|---|---|---|---|
| 1 | 10+ | 4-5 | 10+ | 4-5 | 10+ |
| 2 | 10+ | 4-5 | 10+ | 4-5 | 10+ |
| 3 | 2- | 2- | 2- | 2- | 2- |
| 4 | CDA | CDA | CDABB | CDA | CDABB |
| 5 | atm | atm | nav plan charts | atm | nav plan/atm |
| 6 | pull up | pull up | editing/color sep | pu/coll/qc | pull up |
| 7 | yes | no | no | no | no |
| 8 | ACS | | | | |
| 9 | no | no | yes | no | no |
| 10 | no | no | no | no | yes |
| 11 | 1 | 1 | 1 | 1 | 1 |
| 12 | 4 | 2 | 3 | 3 | 3 |
| 13 | 5 | 2 | 1 | 3 | 5 |
| 14 | 5 | 5 | 4 | 3 | 5 |
| 15 | B | B | B | c | b |
| 16 | A | A | C | c | c |
| 17 | 10+ | 2- | 10+ | 2- | 2- |
| 18 | | A | A | A,B,C | C |
| 19 | 4- | 4- | | 4- | 4- |
| 20 | E | D | | | C |
| 21 | no | yes | yes | no | no |
| 22 | no | no | no | no | no |
| 23 | no | no | yes | yes | yes |
| 24 | | | CDAP table | | tolerance for chart |
| 25 | no | no | no | no | no |
| 26 | | 2 | 3 | 4 | 3 |
| 27 | 4 | 4 | 5 | 4 | 5 |
| 28 | 21-40% | 41-60% | 0-20% | | 0-20% |
| 29 | 41-60% | 41-60% | 21-40% | | 0-20% |
| 30 | 0-5% | 6-10% | 6-10% | 6-10 | 6-10% |
| 31 | 0-5% | 0-5% | 6-10% | 0-5 | 0-5% |
| 32 | 6-10% | 0-5% | 6-10% | 0-5 | 0-5% |
| 33 | C | C | C | BC | BC |
| 34 | A | B | B | B | B |
| 35 | | C | C | C | C |

Table F.1 (Continued)

contradicted the comments provided by cartographers at DMA facilities during visits by ZYCOR personnel.

## F.3 SURVEY RESPONDENTS

There were 29 valid survey responses. Twelve of these were from DMAHTC and 17 from DMAAC. DMAHTC respondents were primarily from the Topographic Analysis section. DMAAC respondents were primarily from the Cartography Department.

The first 8 survey questions were designed to gather information about the training and experience of the respondents. The cartographers who completed this survey are, in general, very experienced cartographers with DMA. Seventeen of them reported having 10 or more years experience; the average experience of the remaining 12 was 3.9 years. Only one respondent reported less than 2 years experience.

The respondents were for the most part trained in manual cartography by DMA. All but one of the respondents reported that their entire work experience in cartography had been at DMA. Only 6 reported formal cartographic training of more than 2 years outside of DMA. And only 3 had experience with computers in performing their cartographic tasks.

## F.4 SURVEY RESULTS

Responses to questions 9-35 in the survey are provided in this section. In the survey, the questions were divided into groups roughly correspondng to line generalization and feature displacement and organized within those two groups according to the type of response required. In this section the two groups are organized by related questions rather than type of response. Possible answers are shown in parenthesis after each question.

### F.4.1 Generalization

#### F.4.1.1 Relationships Among Feature Types

##### F.4.1.1.1 Questions and Responses

**10. When generalizing contours and drains do you delineate the same amount of detail for the line characteristics from both?**

(yes/no)

Response: 13 yes/16 no

**11. When generalizing contours how important is it that they cross roads at right angles?**

(1=unimportant,...,5=very important)

Response: 2.6 average

**12. When generalizing contours how important is it that they show sharp turnbacks when crossing drains?**

(1=unimportant,...,5=very important)

Response: 4.0 average

**13. If you delete a segment of drainage during generalization how important is it that the generalized contours represent the deleted drainage?**

(1=unimportant,...,5=very important)

Response: 3.8 average

##### F.4.1.1.2 Analysis

The response to question 10 supports the idea that a multitude of algorithms or at least varied algorithm parameters will be required to perform generalization on a single product. Other responses indicate the importance of various special cases which are necessary in contour generalization. A good algorithm apparently must be tied to drainage patterns. Selection of parts of the drainage network for inclusion in the final product should be done after the generalization of the contours.

Averaged over all respondents the requirement that contours cross roads at right angles seems not very important. However, this question showed significant variation between the two centers. For 17 respondents at DMAAC the average was 1.8 while for 11 respondents at DMAHTC the average was 3.8.

F.4.1.2 Global Versus Local Considerations

F.4.1.2.1 Questions and Responses

**15. When generalizing relief which is more important to represent correctly: contour character or natural feature character?**

(A. Contour, B. Feature, C. Equal, D. Neither)

Response: 2A/17B/10C/0D

F.4.1.2.2 Analysis

The respondents indicated a strong interest in preservation of topographic detail and an unwillingness to compromise this for contour character. This indicates difficulties are to be expected when using line orientated algorithms to smooth contour data.

F.4.1.3 Exaggeration and Relocation

F.4.1.3.1 Questions and Responses

**16. When generalizing a contour what should be emphasized and retained?**

(A. Ridges on high side of contour, B. Valleys between the ridges, C. They are of equal importance, D. Neither is important)

Response: 6A/0B/22C/0D

**17. When generalizing contours, how often do you deviate from the input data to emphasize important features which would not otherwise be visible at the reduced scale?**

(A. 2 or less per pull-up, B. 3-6 times per pull-up, C. 7-10 times per pull-up, D. more than 10 times per pull up)

Response: 10A/11B/5C/2D

**33. Given a drain and a road following a generally parallel path what should be done if the road crosses the drain several times and the crossing cannot be easily shown at the reduced scale?**

(A. Straighten out drain to one side of road, B. Straighten out road to one side of drain, C. Maintain character of both, D. Delete the overlapping portion of the drain)

Response: 0A/7B/22C/1D

F.4.1.3.2 Analysis

The majority of the respondents gave equal importance to ridges and valleys. A few favored emphasis of ridge lines which might correspond to high points on a map.

*Exaggeration of detail appears to play a limited roll* in the creation of individual pull-ups. However, 25 or more pull-ups may go into the creation of a single product. Thus exaggeration may take place scores of times for a single product.

F.4.1.4 Consistency

F.4.1.4.1 Questions and Responses

**9. Do you feel it is acceptable to over generalize contours in extremely congested areas of a map?**

(yes/no)

Response: 14 yes/15 no

**14. How important is it to generalize uniformly over the entire final product?**

(1=unimportant,...,5=very important)

Response: 4.3 average

**18. How can you tell that you are doing the correct amount of line generalization?**

(A. By looking at the whole pull-up, B. Comparison with previous work, C. Study of specifications, D. Reference to line weights on the pull-up)

Response: 16A/9B/6C/3D/2E

**27. How important is it to have consistent rules for selection for the entire map?**

Response: 4.5 average

F.4.1.4.2 Analysis

It was the primary intention of these questions to learn whether cartographers consciously adjust the amount of detail they pick up from source material as the amount of information content varies. The response to 9 indicated that variations might be expected in contour generalization. The responses to 14 and 27 did not agree with the roughly equally distributed response to question 9. Possibly the wording led responents to associate non-uniform generalization and non-consistent selection with poor quality work.

The wide range of responses to question 18 with an emphasis on A tends to indicate that generalization is based on intuition and subjective evaluation rather than explicit quantifiable standards.

F.4.1.5 Conceptual Limitations on Generalization Process

F.4.1.5.1 Questions and Responses

**19. What is the maximum ratio between source map scale and output map scale for one step generalization?**

(A. less than 4, B. 4-5, C. 6-7, D. 8-9, E. 10 or more)

Response: 10A/9B/5C/1D/1E

**20. What is your reason for this answer to question 19?**

(A. It is a function of the source data, B. Too many features on the source document may be retained when the scale is reduced more in one step, C. When collecting data onto pull-ups there is a limit to the width of the line which can be used to represent the feature at the reduced scale, D. One sheet at the source scale contains too little information at the target scale to comprehend how it fits in the total product. E. Other)

Response: 7A/11B/5C/4D/2E

F.4.1.5.2 Analysis

The majority response placed a limitation of about 5 on the scale change ratio which could be handled in one step generalization. This implies a multistep generalization process if, for example, it is desired to create a 1:500,000 scale map from 1:25,000 scale source material. In automated map generalization *efficient* use of zoom capabilities of a graphics terminal may make such a restriction unimportant.

F.4.2 Displacement

F.4.2.1 Number and Types of Data Elements Involved in Displacement

**28. What percentage of feature displacement decisions involve moving only point data?**

(A. 81-100, B. 61-80, C. 41-60, D. 21-40, E. 0-20)

Response: 0A/2B/6C/3D/16E - 36 average (using center values)

**29. What percentage of feature displacement decisions involve moving line data?**

(A. 81-100, B. 61-80, C. 41-60, D. 21-40, E. 0-20)

Response: 2A/1B/8C/8D/8E - 35.9 average (using center values)

**30. What percentage of feature displacement decisions involve 3 or more features?**

(A. more than 50, B. 26-50, C. 11-25, D. 6-10, E. 0-5)

Response: 1A/3B/3C/11D/9E

F.4.2.1.2 Analysis

Moving only point data should be the easiest part of an automated feature displacement algorithm. The average for question 28 for DMAAC (48.8) was considerably higher than the average for DMAHTC (20.9).

The automation of the process is more difficult when more features require movement at one time. Respondents felt this happened relatively seldom. This may mean that more complex problems are handled by considering only two or three features at a time.

F.4.2.2 Hierarchies

F.4.2.2.1 Questions and Responses

**25. Does name placement ever lead to displacement problems?**

(yes/no)

Response: 16 yes/13 no

**34. If there is a conflict between a building and a feature defined by a contour, which one has priority?**

(A. building, B. feature)

Response: 4A/23B

**35. How do you handle a political border if it conflicts with a more important linear feature?**

(A. Move the border, B. Move the border and disregard its character, C. Delete section of border, D. other)

Response: 3A/0B/17C/8D

F.4.2.2.2 Analysis

Although the wording of question 25 could lead to ambiguities, it seems that name placement does force feature displacement decisions and therefore can not be treated as a completely independent problem if current standards are to be met.

F.4.2.3 Alternative Solutions to Displacement

F.4.2.3 Questions and Responses

**21. Is it permissible to ignore symbolization specifications to resolve a difficult feature displacement problem?**

(yes/no)

Response: 11 yes/18 no

**22. Is it permissible to change the classification of a feature to resolve a difficult feature displacement problem?**

(yes/no)

Response: 2 yes/27 no

**31. What percentage of feature displacement decisions require the amalgamation of features?**

(A. more than 50, B. 26-50, C. 11-25, D. 6-10, E. 0-5)

Response: 3A/3B/4C/7D/11E

F.4.2.3.2 Analysis

A sizable minority of the respondents felt that it is permissible to ignore symbolization specifications to resolve a difficult displacement problem. The split was even at DMAHTC at 6 to 6. A strong majority believe that changing feature classification is not permissible.

F.4.2.4 Influences of Guidelines and Specifications

F.4.2.4.1 Questions and Responses

**23. Are there specific limitations on how much a feature may be displaced on the final product?**

(yes/no)

Response: 20 yes/9 no

**24. If answer to 23 is "yes", please describe limitions?**

Response: varied

**26. How important is it to annotate a feature which has been significantly displaced to reflect its reduced positional accuracy?**

(1=unimportant,...,5=very important)

Response: 3.9

**32. For what percentage of feature displacement decisions do the available guidelines fail to provide the necessary relative hierarchies?**

(A. more than 50, B. 26-50, C. 11-25, D. 6-10, E. 0-5)

Response: 3B/2C/7D/15E

F.4.2.4.2 Analysis

The majority of those who gave a yes in #23 cited map specifications as providing the limitations. Other people cited line widths, feature size, or minimum visible separation as providing the limitations.

The general feeling is that existing hierarchies define the problem well.

## APPENDIX G
## SELECTION

For this report, ZYCOR has been studying line generalization and feature displacement in as narrow a sense as possible. As is discussed in Section 2.1, the DMA definitions of generalization exclude the selection problem. This presents difficulties since some authors (Note: Robinson does not) include selection as an integral part of the generalization process. This appendix gives a very brief overview of the work that has been done on selection.

### G.1 EMPIRICAL WORK

The selection aspects of this problem have been addressed by a number of authors in a mathematical approach based on empirical work. Topfer and Pillewizer (*1966k*) provided the first such approach in a number of papers in the 1960's. They suggested a selection law which is designed to determine what percentage of source map objects should be selected for a new map as a function of the relative scale changes between the two maps. This rule has had a number of different forms in different papers. In its most general form it is:

$$Nf = Na\ K1\ K2\ SQRT(Ma/Mf)$$

where Nf is the number of objects which can be shown at the derived scale. Na is the number of objects shown on the source map, K1 and K2 are coefficients determined by the size and importance of the particular objects. Ma is the scale denominator of the source map and Mf is the scale denominator of the derived map.

The above formula does not attempt to deal with changes in distribution of objects across a source map. With this in

mind, Srnka (1970) suggests an approach which in one formulation follows the relationship:

$$Nb\% = Ks\ Na^{-Kd}$$

where Nb% is the percentage of objects on the derived map, Na is the number of objects on the base map, Ks is a coefficient defining the general selection standard for a particular object and Kd a coefficient which takes account of changes in the density of elements in particular parts of the reference map.

All these rules are highly empirical and give no cartographic guidance as to what should be retained. This approach has not been studied much in the English language, however, based on citations in Srnka's paper this is investigated fairly seriously in Soviet block countries.

## G.2 SELECTION AND GENERALIZATION

Definitions in the MCG carefully separate the selection and generalization tasks. Whether this is possible is a subject of considerable theoretical and practical interest (Steward, 1974). A complete separation seems impossible.

This is not a standard interpretation of selection. Usually, it refers to which features will be portrayed, not which part of a feature. The generalization algorithms as defined "smoothing the character of a feature" should address the problem of "within feature" retention.

## APPENDIX H
## CURRENT RESEARCH AND DEVELOPMENT BY NON-DMA CARTOGRAPHERS

In an effort to determine the present state of research in automated line generalization and feature displacement ZYCOR wrote letters to cartographers and computer scientists in the private, public, and educational sectors in the United States, Canada, and Europe. This appendix discusses the responses which were received.

The information was gathered from persons known to have worked on or to be working on manual or automated line generalization or feature displacement. Unless a specific article or algorithm produced by the researcher was of interest to this contract, a generic letter was sent inquiring about their activities and present research being done in this area.

Most of the individuals contacted did not provide significant new technical information. However, the respondents did inform ZYCOR of the unpublished research or development tasks of which they were aware. Additionally, some respondents suggested sources of additional information and provided their thoughts on the feasibility and need of such research.

The amount of work being done in automated line generalization and feature displacement is relatively small. This lack of research is attributed in an absence of new information and ideas for automated line generalization and feature displacement according to some sources. A prime illustration of this can be seen in the number of researchers having switched their focus from investigating automated line generalization and feature displacement to other cartographic research efforts.

One response, from the Ministry of Defense in England, was very typical of many of the responses we received. No one in the Ministry of Defense is presently investigating line generalization or feature displacement. They believe that it is necessary to concentrate their efforts on other automated cartograhic processes; "whilst we recognize the need for this work, our present assessment in the light of limited resources, is that greater benefit can be gained in developing other areas of automated cartography."

However, we were informed of research projects encompassing some aspects of line generalization. Several of these research efforts involve the mathematical comparison of line generalization algorithms. Notably, Thomas Poiker at Simon Fraser University and students at the University of Kansas and Virginia Polytechnic Institute are in the process of conducting or have completed research efforts designed to compare the effectiveness and provide a comprehensive overview of various line generalization algorithms.

Additionally, there are several ongoing research efforts which are investigating topics related to line generalization. In one research project conducted at the University of California at Santa Barbara, Barbara Pfeil Buttenfield is attempting to develop an artificial intelligence program which will enable the program to "learn" how to generalize lines and displace features. This project is still under investigation, therefore no results are presently available. George Jenks, at the University of Kansas, is conducting research aimed at determining the effect of generalized lines on the users perception of the map. Mark Monmonier at Syracuse University is studying cartographic generalization of areal or polygon data for the United States Geological Survey.

No research was discovered which directly addresses automated feature displacement. This lack of research may be a result of the degree of difficulty involved in automating this task. Most of the respondents are difficult procedures to automate.

In general the tenor of the responses was that there is a need for automated line generalization and feature displacement. Most of the responses wished us luck, as if they were aware of something we did not know.

APPENDIX I

RECOMMENDATIONS

This appendix contains ZYCOR's recommendations for further research in line generalization and feature displacement. These are concentrated in three areas. First is the use of line oriented algorithms in smoothing linear cartographic features. Second is the use of DEM smoothing in contour generalization. The third is the use of word maps in the feature displacement problem.

## I.1 LINE ORIENTED GENERALIZATION ALGORITHMS

An automated cartographic system may be expected to use many different line oriented generalization algorithms. Further study in this area should be concentrated on attempting to expand knowledge about candidate algorithms and evaluating the performance of these algorithms.

### I.1.1 Further Development Work

Algorithms identified as angle detection and conic arc fitting both have promising features for use in line generalization but also have significant problems or unresolved details in their implementation. These should be further investigated. For angle detection algorithms it would be desirable to:

- learn whether already identified limitations may be overcome
- quantify the difficulty in controlling these algorithms

For conic arc fitting algorithms it would be desirable to learn

- the best methods for chosing knots where separate arcs meet
- the best way to perform and measure fits
- the best methods of controlling these algorithms

### 1.1.2 Algorithm Evaluation

A process of algorithm evaluation is required. ZYCOR believes that a three step procedure would be valuable. This would investigate details of implementation, identify problems, and finally involve controlled experiments using DMA resources to evaluate algorithm quality.

#### I.1.2.1 Algorithm Implementation

Since generalization of linear features will probably make use of a number of different algorithms evaluation of performance will require the study of a multitude of algorithms. Since generalization of linear features will probably involve interactive processing, speed will be a primary concern. One or more algorithms from each of the categories identified as potential or high potential in Chapter 7 should be coded. In the case of high potential algorithm categories many variations should be investigated while for less likely categories only the best possible choices should be investigated.

These algorithms should be optimized for a particular computer implementation and the relative speed measured. Where possible they should be compared according to measures such as number of points retained for a given tolerance and the amount of time required for certain amount of data reduction. Analytical

comparisons such as those suggested by McMasters (1983a, 1983b) may also be useful.

### I.1.2.2 Initial Data Testing

In cooperation with DMA, certain data test sets should be identified. These might include coast lines, particularly sinuous stream lines, or any other difficult features. If possible a complete network of linear features for a map would be useful. Implemented algorithms should be used on these test sets to identify potential problems such as resultant spikes, significant features deleted, and inability to control algorithm performance.

This testing procedure will be largely subjective. Its primary purpose will be to assist in preparing for the next stage of algorithm evaluation. Input from senior DMA cartographers would be very useful in making these evaluations.

### I.1.2.3 Evaluation at DMA

The performance of line generalization algorithms must be evaluated according to the visual results expected by cartographers. This is not a task which can be done by analytical studies, nor is it something which can easily by done by subjective analysis. A sophisticated evaluation strategy is required.

In order to obtain supportable conclusions and to obtain results in a reasonable amount of time, statistical testing and surveying procedures will be required. It will be necessary to formulate restricted hypothesis about algorithm performance and cartographic goals for particular data and map types and to present the evaluation procedures in such a manner as to support or reject the hypothesis.

For example, generalization of coastline data is of particular interest to cartographers since it involves both a high priority requirement to retain important detail and a need for generally high accuracy. This can easily lead to guesses about which algorithms would perform best for handling such a data type. By presenting properly scaled results from a variety of algorithms including those expected to perform best using a narrow range of control parameters within a suspected range of "correct" values it should be possible to gain confirmation or rejection of this hypothesis. Care needs to be taken to account for line weights and to provide sufficient background detail.

Attempting to resolve too general hypothesis or to obtain too much information in one testing process could easily destroy the testing procedure either by exhausting test subjects or by providing too little in the way of results. Thus it may be useful to attempt to isolate scale and data dependent questions such as algorithm tolerances during this evaluation procedure while the majority of effort is spent on choosing correct algorithms.

## I.2 CONTOUR GENERALIZATION THROUGH DEM SMOOTHING

DEM smoothing should be throughly investigated as a means of contour generalization. Although this is not an entirely risk-free approach to the problem the potential advantages discussed in Chapter 7 demand that this technique be seriously studied.

Among the topics which should be investigated are:

- techniques of correlating DEM roughness with contour roughness
- ways of controlling the amounts of roughness in a DEM and the contours produced from that DEM

- techniques of varying amounts of DEM smoothing by type of terrain

- techniques of tying to drainage and other supplementary data during DEM smoothing and DEM contouring

- identification of DEM grid resolution requirements necessary for the production of large scale DMA maps

- identification of decimation requirements for using particular resolution DEM data to support specified target scale graphic products

- identification of limitations in using DEM contouring compared with current DMA production methods

## I.3 FEATURE DISPLACEMENT

The feature displacement problem suffers from a lack of unifying concepts to guide algorithm development. The word map approach attempts to provide such a framework. The potential usefulness of this approach should be explored. The following topics should be considered for study:

- techniques to extend algorithm capabilities to handle the line and area features

- the use of varying density word maps to optimize conflict detection performance and minimize storage requirements during processing

- methods of problem segmentation to reduce computational loads

- file structures and use of individual bits within computer words to record conflicts, movement directions, past feature positions, etc

- types of interference resolution methods that are compatible with the word map structure

- iterative techniques and movement step sizes to minimize the generation of future conflicts and to maintain topological validity

- storage and CPU impact of such an algorithm on current computer hardware

## APPENDIX J

## GLOSSARY OF TERMS RELATING TO LINE GENERALIZATION, FEATURE DISPLACEMENT AND CARTOGRAPHY

This appendix contains a glossary of cartographic terms relating to line generalization and feature displacement. Because several possible words and defintions are used for many of the same cartographic ideas and techniques, this glossary is provided for uniformity between the DOD and non-DOD uses of words. The source of these definitions is the Glossary of Mapping, Charting, and Geodetic Terms (Defense Mapping Agency, Fourth Edition, 1981).

ACCURACY: The degree of conformity with a standard, or the degree of perfection attained in a measurement. Accuracy relates to the quality of a result, and is distinguished from PRECISION which relates to the quality of the operation by which the result is obtained.

AERONAUTICAL CHART: A specialized representation of mapped features of the Earth, or some part of it, produced to show selected terrain, cultural, and hydrographic features, and supplemental information required for air navigation, pilotage, or for planning air operations. Also called navigation chart.

AIR TARGET CHART: One of the graphics in the Air Target Materials Program designed to provide chart coverage of an area at a scale that permits portrayal of pertinent target detail. The charts provide graphic overprint and textual data relative to radar return information and installations within the area. Air Target Charts are prepared at various scales and are produced as a series of geographically integrated charts.

ALIGNMENT (ALINEMENT): The correct direction, character, and position of a line or a feature in a relation to other lines or features.

ANNOTATION: Any marking or illustrative material for the purpose of clarification, such as numbers, letters, symbols, and signs.

BASE MAP: A map or chart showing certain fundamental information, used as a base upon which additional data of a specialized nature are compiled or overprinted. Also, a map containing all the information from which maps showing specialized information can be prepared.

BATHYMETRIC CHART: A topographic chart of the floor of the ocean.

CARTOGRAPHIC ANNOTATION: The deletion of additional data, new features, or deletion of destroyed or dismantled features on a mosaic to portray current details. Cartographic annotation may include elevation values for airfields, cities, and large bodies of water; new construction and destroyed or dismantled roads, railroads, bridges, dams, target installations, and cultural features of landmark significance.

CARTOGRAPHIC FEATURE: The natural or cultural objects shown on a map or chart. See also TOPOGRAPHIC FEATURE.

CARTOGRAPHIC FILE: A processed file of cartographic information which defines cartographic features sufficiently for reproduction according to acceptable standards.

CARTOGRAPHIC LICENSE: The freedom to adjust, add, or omit map features within allowable limits to attain the best cartographic expression. License must not be construed as permitting the cartographer to deviate from specifications.

CHARACTER: The distinctive trait, quality, property, or behavior of manmade or natural features as portrayed by a cartographer. The more character applied to detail, the more closely it will resemble these features as they appear on the surface of the earth. Contrasted with GENERALIZATION.

COASTAL CHART: A nautical chart intended for inshore coastwise navigation when a vessel's course may carry her inside outlying reefs and shoals, for use in entering or leaving bays and harbors of considerable size, or for use in navigating larger inland waterways.

COMPILATION: The production of a new or revised map or chart, or portion thereof, from existing maps, aerial photographs, surveys, new data and other sources.

COMPILATION HISTORY: Compilation information regarding the development of a map or chart. It explains the problems and their solutions, and aids in simplifying the research and analysis of source materials considered for compilation or revision of other maps or charts. The compilation history

contains information on the planning factors, source materials utilized, control, compilation methods, drafting, reproduction, and edit procedures.

COMPILATION INSTRUCTIONS: Written directions describing cartographic sources and their use in determining information to be compiled. Compilation instructions are not to be confused with SPECIFICATIONS.

COMPILATION MANUSCRIPT: The original drawing or groups of drawings, of a map or chart as compiled or constructed from various data on which cartographic and related detail is delineated in colors on a stable-base medium. A compilation manuscript may consist of a single drawing called a base manuscript, or because of congestion, several overlays may be prepared showing vegetation, relief, names, and other information. Since the latter is usually the case, the base together with its appropriate overlays are collectively termed the compilation manuscript. The general term "manuscript" is not recommended without adequate qualification.

COMPILATION SCALE: The scale at which a map or chart is delineated on the original manuscript. This scale may be larger than the reproduction scale.

CULTURAL DETAILS: See CULTURE.

CULTURAL FEATURES: See CULTURE.

CULTURE: Features of the terrain that have been constructed by man. Includd are such items as roads, buildings, and canals; boundary lines, and, in a broad sense, all names and legends on a map. Also called cultural details; cultural features; manmade features.

DATA REDUCTION: Transformation of observed values into useful, ordered, simplified information.

DEPTH CURVE: A line on a map or chart connecting points of equal depth below the hydrographic datum. Also called isobath.

DISPLACEMENT: The horizontal shift of the plotted position of a topographic feature from its true position, caused by required adherence to prescribed line weights and symbol sizes.

DRAINAGE: In mapping, all features associated with water, such as shorelines, rivers, lakes, marshes, etc.

DRAINAGE PATTERN: The pattern or overall appearance made by the network of drainage features on a map or chart.

EDITING: The process of checking a map or chart in its various stages of preparation to insure accuracy, completeness, and correct preparation from and interpretation to the sources used, and assure legible and precise reproduction. Edits are usually referred to by a production phase, such as compilation edit, scribing edit, etc.

ENGRAVER: See SCRIBER.

FILM MOSAIC: See PANEL BASE.

GENERALIZATION: Smoothing the character of features without destroying their visible shape. Generalization increases as map scale decreases. Compare with CHARACTER.

HARBOR CHART: A nautical chart intended for navigation and anchorage in harbors and smaller waterways.

HYDROGRAPHIC CHART: A nautical chart showing depths of water, nature of bottom, contours of bottom and coastline, and tides and currents in a given sea or sea and land area. Also called marine map; nautical chart.

JOINT OPERATION GRAPHICS (JOGS): The standard 1:250,000 scale Department of Defense cartographic product which may be produced in any of the following three versions to meet the validated Unified and Specified Commands and the Military Departments area requirements: the JOG/G (Series 1501) is designed to meet ground use requirements; JOG/A (Series 1501 Air) is designed to meet air use requirements; the JOG/R (Series 1501 Radar) is the Air Target Materials version in support of radar/intelligence planning and operations requirements.

LIFT: See SELECTION OVERLAY.

MANMADE FEATURES: See CULTURE.

MANUSCRIPT: The original drawing of a map as compiled or constructed from various data, such as ground surveys and photographs. See also MULTI-USE MANUSCRIPTS (MUM).

MAP ACCURACY SPECIFICATION: Specifications which set up standards to which the finished map must adhere. Not to be confused with the United States Map Accuracy Standards. MAP ACCUARCY STANDARDS: See UNITED STATES NATIONAL MAP ACCURACY STANDARDS.

MAP ADJUSTMENT: An adjustment of the horizontal position of maps to control points or to a specific grid plotted on the map projection at compilation scale.

MAP-CONTROLLED MOSAIC: A technique of constructing mosaics by using topographic maps as the basis for control and orientation purposes. The method may be used in preparing both controlled and semicontrolled mosaics although its use is preferred with the latter.

MARINE MAP: See HYDROGRAPHIC MAP.

MOSAIC: See PANEL BASE.

MULTI-USE MOSAIC (MUM): A manuscript compilation that, as a minimum, establishes the contours, spot elevations, and includes the horizontal position of the significant planemetric features. It is suitable for use in completing a topographic map or an aeronautical or nautical chart; and the integrity of its horizontal and vertical accuracy is retained in all end products made from it.

NAUTICAL CHARTS: See HYDROGRAPHIC MAP.

NAVIGATION CHART: See AERONAUTICAL CHART; HYDROGRAPHIC CHART.

OVERCHARGING: Applying excessive additional information (aeronautical or nautical) to a map or chart resulting in clutter.

PANEL: See PANEL BASE.

PANEL BASE: The complete assembly of pieces of film positives onto a grid or projection which is used as a base for compilation. Also called film mosaic; panel.

PANELING: Cutting a film positive or a map in which some distortion is involved, into several pieces and cementing them in place, on a projection constructed on a stable-base medium, in such a way that the error is distributed in small amounts throughout the area rather than being localized.

POSITIONAL ACCURACY: A term used in evaluating the overall reliability of the positions of cartographic features on a map or chart relative to their true position, or to an established standard.

POSITIONAL ERROR: The amount by which a cartographic feature fails to agree with its true position.

PRECISION: The degree of refinement in the performance of an operation, or the degree of perfection in the instruments and methods used when making the measurements. Precision relates to the quality of the operation by which the result is obtained, and is distinguished from ACCURACY which relates to the quality of the results.

PULL-UP: See SELECTION OVERLAY.

SAILING CHART: A small-scale chart used for offshore sailing between distant coastal ports and for plotting the navigator's position out of sight of land and as he approaches the coast from the open ocean. They show offshore soundings and the most important lights, outer buoys, and natural landmarks which are visible at considerable distances.

SCRIBER: An instrument holding a scribing point; used for scribing on coated plastics. Also called engraver; graver, scribing instrument. See also engraver subdivider; rectagraver; rigid tripod engraver; straight line graver; swivel graver; turret graver.

SELECTION OVERLAY: A tracing of selected map source detail compiled on transparent material; usually described by the name of the feature or details depicted, such as contour overlay, vegetation overlay. Also called LIFT; PULL-UP; TRACE.

SOURCE MAPS: The map used for the selection of map or chart detail.

SPECIFICATIONS: The rules, regulations, symbology,, and a comprehensive set of standards which have been established for a particular map or chart series or scale group. Specifications vary with the scale and the purpose of the graphic.

TOPOGRAPHIC FEATURE: See TOPOGRAPHY.

TOPOGRAPHIC MAP: A map which presents the vertical position of features in measurable form as well as their horizontal positions.

TOPOGRAPHY: The configuration of the surface of the earth, including its relief, the postion of its streams, roads, cities, etc. The earth's natural and physical features collectively. A single feature such as a mountain is termed a topographic feature. Topography is subdivided into hypsography (the relief features), hydrography (the water and drainage features), culture (manmade features), and vegetation.

TRACE: See SELECTION OVERLAY.

UNCONTROLLED MOSAIC: A mosaic composed of uncorrected prints, the detail of which has been matched from print to print without ground control or other orientation.

UNITED STATES NATIONAL MAP ACCURACY STANDARDS: Horizontal Accuracy: For maps at publication scales larger than 1:20,000, 90% of all well-defined features, with the exception of those unavoidably displaced by exaggerated symbolization, will be located within 1/30 inch (0.85 mm) of their true geographic positions as referred to the map projection; for maps at publication scales of 1:20,000 or smaller, 1/50 inch (0.50 mm). Vertical Accuracy: 90% of all contours and elevations interpolated from contours will be accurate within one-half of the basic contour interval. Discrepancies in the accuracy of the contours and elevations beyond this tolerance may be decreased by assuming a horizontal displacement within 1/50 inch (0.50 mm). Commonly referred to as MAP ACCUARACY STANDARDS.